CHAPTER 1

Towards Complex Human Robot Cooperation Based on Gesture-Controlled Autonomous Navigation

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This paper presents a new approach for human robot co- operation, where a mobile ground robot is provided with the ability of following a person that has been detected with a Kinect sensor. It can plan a trajectory to follow the person and avoid obstacles that appear in the environment in an autonomous way. It has been developed to work in coordinated tasks where the person needs to exchange data and take advantage of the sensors, communications and other capabilities of the robot, in order to accomplish a collaborative labor with a situation of proximate interaction. The UGV is controlled by reading some predefined gestures of the person, and the autonomous navigation is based on a well established navigation scheme. A set of initial experiments demonstrate the feasibility of the system.

1 Introduction

A new generation of service robots has emerged. Robots are moving out from factories, and entering our houses and every day lives. The spread of these robotic systems and the frequent interaction with humans in these scenarios led to the broadening of another subject area: human-robot interaction, also known as HRI.

Human-robot interaction is dedicated to understanding, designing, and evaluating robotic systems to be used by or with humans and involves a continuous communication between humans and robots, where communications are implementable in different ways. We can distinguish two general categories of interaction:

- Remote interaction: humans and robots do not share the same physical workspace, being separated spatially or even temporally (e.g. the Mars Rovers are separated from the Earth both in space and time);
- Proximate interaction: humans and robots are located within the same workspace (for example, service robots may be in the same room as humans).

We have focused on a proximate interaction where the human was in charge of the guidance of the collaboration task. In the experiment, the person walks randomly through the obstructed scenario while he gives positioning orders to the robot by body gestures. Then, the robot follows his partner by autonomous navigation, at the same time that it must achieve a specific relative position to the person in response of the given gestures. At this point, our proposal starts to differ to other research works by not only using the gesture control to simple teleoperation, even more, getting a team joint formation by human and robot. This formation is maintained meanwhile they are avoiding the obstacles on their way.
Until there, two levels of interaction are entailed: gesture guidance and autonomous tracking. But our work goes further and presents a novel approach to the HRI that includes a third level of interaction. It involves a collaborative task simulation where one UGV and one human have to continuously exchange information to accomplish a joint labor.

2 Related Work

Gesture control for robots is not a novel idea, in fact, (Waldherr et al.)[12] gives a good approach to a human tracking, task assignment and navigation control for a mobile robot using gesture recognition techniques. Their system follows the operator arm with a camera and a computer vision system in order to identify preconceived configurations and movements; information related to different actions. Nonetheless, their tracking module is unable to follow people who do not face the robot and the distance between the robot and the operator has to be maintained constant.
Nowadays, there has been a lot of research works addressing the RHI through gesture or posture identification using Kinect®. Most of the approaches are oriented to the study of humanoids and articular robots motion. (Igorevich et al.) [9] controls the arms of the humanoid Huno Robot. (Quian et al.) [8] gives three kinds of tasks to a pair of articular robotic

arms. (Yang et al.)[7] have developed a system to achieve the simulation and the NAO robot control using the skeleton representation of the human posture. (Lei et al.)[14] goes further and uses the joint angles representation of the skeleton for giving to the system an easy operator exchange. (Chang, Nian, Chen, Chi, & Tao, 2014)[4] studies the RHI language through the semaphore alphabet recognition.

This kind of HRI has been also explored using mobile robots. Perhaps, the closest study to our approach is (Bonanni, 2011)[3]. He also integrates a gesture recognition module with a people tracking system in a follow people task for a UGV. Nevertheless, their robot is not available to make a full navigation labor and it has no other function but to follow the operator.

It can be appreciated that none of the works listed above achieves the full operational requirements needed for the task that we are intending. Even more, everyone approaches to the HRI only from the technical view, but not from a collaborative goal like our proposal.

3 The Mobile Platform

The platform is based on the Summit XL® platform by Robotnik® (figure 1). It has skid-steering kinematics. The robot can move autonomously or it can be teleoperated using video feed from an on-board camera. Furthermore, it is equipped with a small form factor PC which allows deploying all the data processing and navigation algorithms in a fully autonomous manner.

Various sensor modalities are also present. The odometry is provided by an encoder on each wheel and a high precision angular sensor assembled inside the chassis.

One Hokuyo UTM-30LX-EW laser rangefinder is mounted on the platform, it can scan a 270º semicircular field, with a guaranteed range that goes from 0.1 to 30 meters and a maximum output frequency of 40Hz. It is placed at 60 centimeters over the ground in the central part of the robot.

A Novatel OEM-4 GPS engine is also used; it can offer centimeter level positioning accuracy with a frequency of 2Hz.

The MicroStrain 3DM-GX3 25 which is a high-performance, miniature Attitude Heading Reference System (AHRS) is mounted inside the robot. Additionally PTZ camera is placed in the front of the robot and provides video in real-time.

Fig 1. Summit Robot

4. Finding and Tracking People

The system presented in this paper aims to build a robotic system that firstly looks for a person to interact with, then initiates interaction, and uses hand gesture recognition to detect a pointing gesture and the depth value to follow the person. Gestures detected by the robot are analyzed and compared with a database of gestures to perform the corresponding action (stop, turn on itself, move aside, etc). Meanwhile, the value of the distance obtained between the person and the robot is continuously analyzed to always keep a safe distance from the person. It also ensures that wireless communication being using by the robot sensors is not interrupted.

4.1 Detecting people

Traditionally, robotics systems need special marks that stand out of the environment to conduct a robust tracking. However, with the use of Kinect, procedures have changed and it is capable of detecting people almost automatically.

One of the packages that OpenNI offers for ROS performs automatic detection of persons. It has several strengths, such as automatic detection of people entering the scene and removing them when they leave it. Another feature that facilitates the task, is that the when a person is placed in a certain position, the position of Psi (which can be seen in figure 2), it creates a relationship with the person and starts the tracking of the person. Figure 3 shows the flowchart for setting a target on a person.

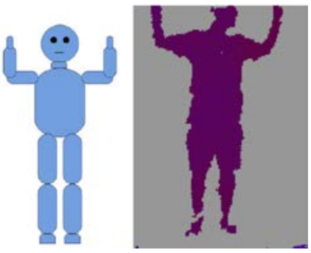

Fig 2. Psi pose for detecting the tracking objective (left). Person in psi pose detected by the Kinect (right).

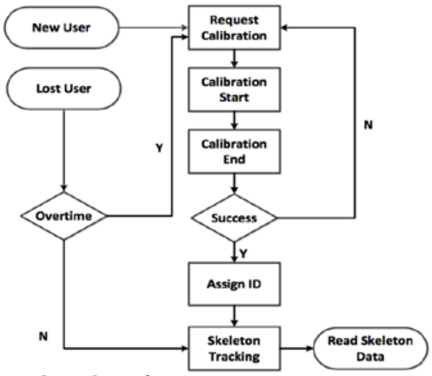

Fig 3. Flowchart for setting a target on a person

4.3 Control strategy

As far as we know, for the Summit XL robot, linear motion X and angular rotation Z are useful for control strategy. In the coordinate, positive X axis is toward the front of robot, positive Y axis is along the right side of robot, and positive Z axis points to sky. The Robot Control module converts some signals generated from other modules into the linear and angular velocity of the UGV. The Skeleton Tracking module can generate and send six different signals through identifying some simple motions and events done by the person. The signal for obstacle avoidance is generated and sent by the laser module and the Kinect depth camera. Then the mobile robot will make different reactions according to different signals (table 2), the distance of the person and the obstacles detected in the scene.

Table 1. Movement detect by the Summit XL

Person pose	Summit Action
Arms Down	Follow me

Left Arm Up	Position at my left
Right Arm Up	Position at my right
Arms Up	Stop
Left Arm on Head	Twist on its self
Ducking	Abort mission

Arms Down: This pose makes the mobile robot follow the person through tracking the position of the person's center of mass. If the center of mass position is in the center of coordinate system and the distance between the person and the mobile robot is appropriate, the mobile robot will keep still. Otherwise, the mobile robot will take some actions to maintain the person's center of mass in center of its view sight and the distance between them within the specified range. When the robot detects more than one person in the scene, it will follow always the person that has identify himself with the Psi pose and ignore the rest.

Left Arm Up: This pose will send to the robot the order to pose it at the left of the person.

Right Arm Up: This pose will send to the robot the order to pose it at the right of the person.

Arms Up: This pose will send to the robot the order to stop moving.

Left Arm Head: This pose will send to the robot the order to twist on its self.

Ducking: This pose will send to the robot the order to stop moving, abort the mission and desvinculate the person.

Furthermore, if the robot detects an obstacle (with it laser or ToF camera) during the trajectory, it is able to find an alternative path to avoid the obstacle and get to the objective point. Once the point is reached if the person continues there, the robot will follow him, otherwise, will wait until it detects again the person.

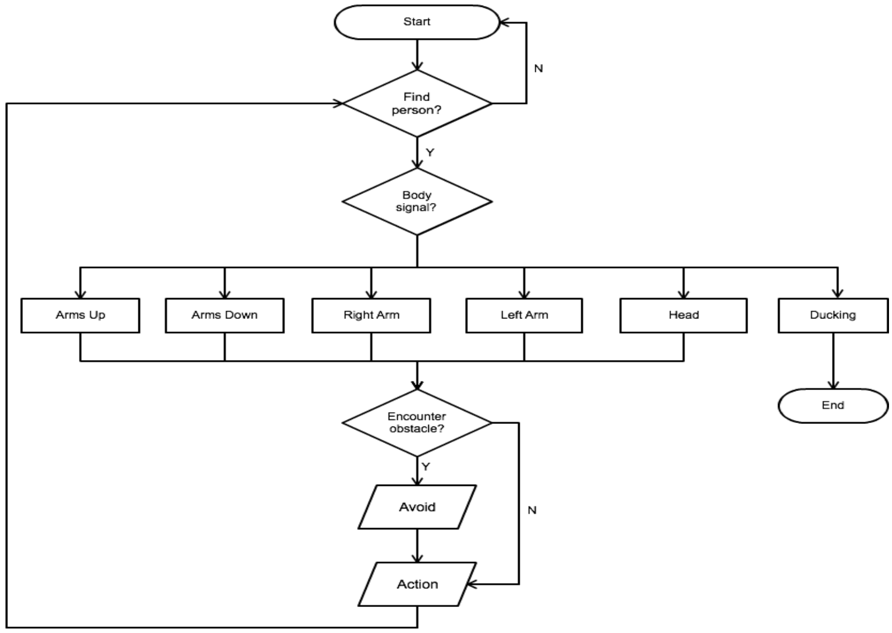

Fig 4. Algorithm to track a person and avoid obstacles

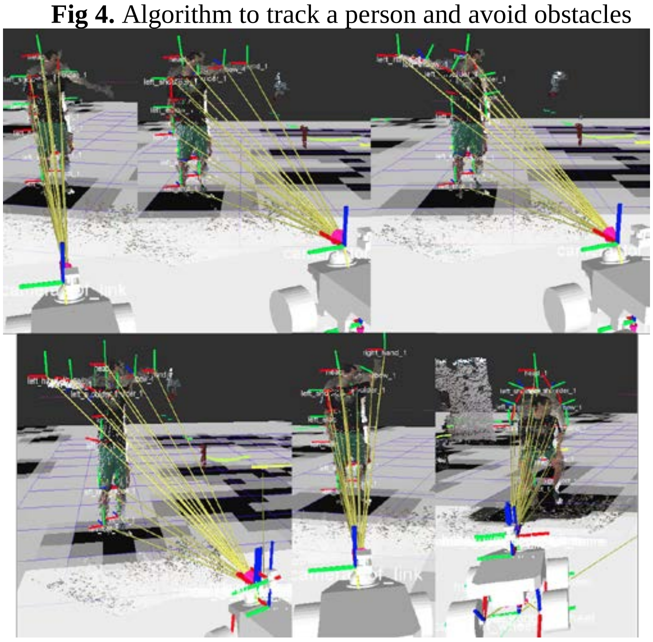

Fig 5. Poses detected by the robot

5 Experimental Results

In order to evaluate the behavior of the HRI collaborative task, the person walked randomly around an indoor scenario with obstacles. The robot should follow him while it was receiving orders through the gestures listed above. Also, the person was constantly streaming arbitrarily data to the robot wirelessly. The purpose of this was simulate the information that would be collected by sensors in the aim of this work. If the robot loosed completely the target or stopped receiving data, the trail would be considered failed. The test results show the good performance of the implemented system. The robot achieves an 88% of efficiency in the gesture recognition and it had not problems to follow the target with obstacle avoidance; this fact can be extracted from the zero collisions obtained in the ten trials.

6 Conclusions

In this article a novel approach to HRI is described. It proposes collaborative tasks between human and robot with three different kind of interaction. The first one was a direct control of the robot movements using a gesture recognition system. The second one was a following behavior using tracking techniques including obstacle avoidance navigation. The third one was a continuous exchange of information which implies the ability of the robot to work in a collaborative task. This work went further of previous ones adding the interaction factor over the technical needs for the development of the labor.

Acknowledgements

This work was supported by the Robotics and Cybernetics Group at Universidad Politécnica de Madrid (Spain), and funded under the projects: PRIC (Protección Robotizada de Infraestructuras Críticas; DPI2014-56985-R), sponsored by Spanish Ministry of Economy and Competitiveness and RoboCity2030-III-CM project (Robótica aplicada a la mejora de la calidad de vida de los ciudadanos. fase III; S2013/MIT- 2748), funded by Programas de Actividades I+D en la Comunidad de Madrid and co-funded by Structural Funds of the EU.

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